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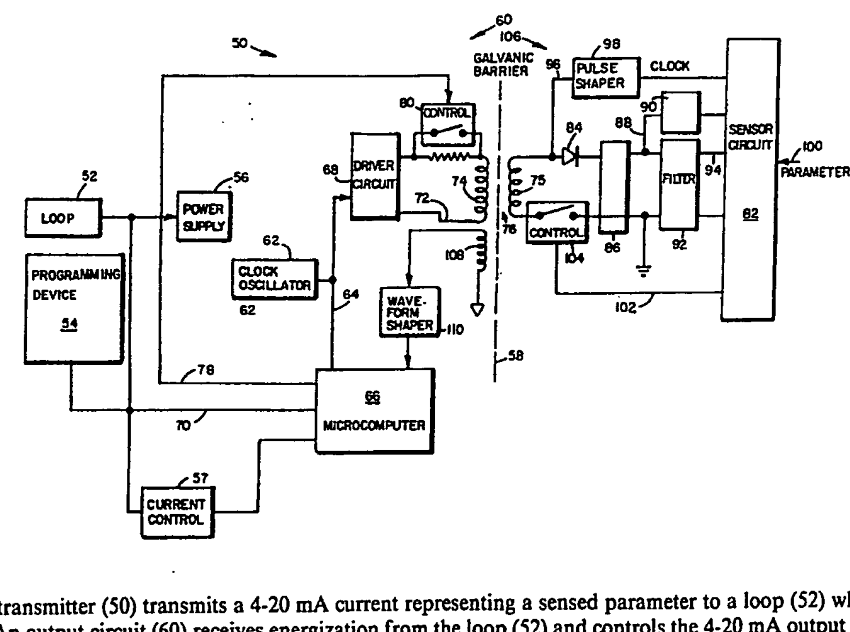
(54) Title: MULTIFUNCTION ISOLATION TRANSFORMER



(57) Abstract

A process transmitter (50) transmits a 4-20 mA current representing a sensed parameter to a loop (52) which energizes the transmitter (50). An output circuit (60) receives energization from the loop (52) and controls the 4-20 mA output as a function of a sensor data input. The output circuit (60) further generates a transformer driver output which also serves as a clock for isolated circuitry (106). A sensor circuit (82) generates a transformer driver output representing the sensed parameter. An isolation transformer (76) driven by the driver output excites the sensor circuit (82) and provides a clock reference as a function of the driver output oscillation to the sensor circuit (82). The isolation transformer (76) is a single coupling device which couples energization, clock reference, sensor data and programming data across an electrically insulating barrier between the output circuit (50) and the sensor circuit (82).

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MULTIFUNCTION ISOLATION TRANSFORMER

BACKGROUND OF THE INVENTION

This invention relates to a transmitter having loop circuitry receiving energization from a current loop and controlling the loop current to represent a parameter sensed by sensor circuitry in the transmitter.

In transmitter circuits, a galvanic barrier is often desired between loop circuitry and sensor circuitry in order to block flow of undesirable ground currents through sensitive transmitter circuits. Magnetic transformers and optocouplers have been used to couple signals and power between isolated circuits on opposite sides of the barrier, while providing DC isolation between them. Typically, the loop circuitry couples energization across the barrier to energize the sensor circuitry while the sensor circuitry returns a sensor signal indicating the sensed parameter back across the barrier to the loop circuitry. In U. S. Pats. 3,764,880 and 4,206,397, for examples, a single transformer provides galvanic isolation between a circuit connected to a loop and sensor circuitry. The single transformer couples energization in one direction and a sensor signal in an opposite direction across the barrier.

Transmitters can be of a programmable type, programmed by a digital signal from a programming device connected to the loop. For each installation, there is a desire to adjust or program the transmitter to have an output range and other characteristics matched the installation. In some transmitter arrangements, it is desirable to have the transmitter's sensor circuitry be programmable so that that sensing is specifically adapted to the range of the input variable of interest

in a particular installation. However, the digital programming signals generated on the loop side of the galvanic barrier must be kept isolated from the sensor circuitry which is to be programmed on the other side of the barrier. There is thus a need to couple digital programming signals across the barrier, leading to an apparent need for another galvanically isolating coupling device to be added to the transmitter. Digital sensor circuitry typically would also require a timing reference or clock for support of its functions, and there is further a desire to have a single clock supporting circuitry on both sides of the barrier, leading to an apparent need for yet another galvanically isolating coupling device such as a transformer or optical coupler. Each additional coupling device can increase complexity and power consumption, which can be limited when the transmitter is energized by a milliampere level loop current such as a 4-20 mA loop current.

There is thus a desire to provide a transmitter which provides galvanically isolated coupling of energization, a signal representative of the the sensed parameter, a timing reference, and a programming signal across a barrier, but avoiding the cost, complexity and increased power consumption of adding multiple isolating coupling devices.

SUMMARY OF THE INVENTION

A transmitter is provided with a single galvanically insulating coupling device which isolates loop circuitry from sensor circuitry. Transmitter circuitry is arranged to utilize the single coupling device to isolatingly couple not only power and a representation of a sensed parameter, but also

programming data simultaneously across a galvanic barrier.

A transmitter sends its output representing a sensed parameter to a loop or circuit which energizes the transmitter. An output circuit in the transmitter receives the energization from the loop and controls the transmitter output as a function of a sensor data input. The output circuit further generates an oscillating driver output. A sensor circuit generates a sensor data output representing the sensed parameter. Isolation means driven by the driver output excite the sensor circuit and provide a clock reference as a function of the driver output oscillation to the sensor circuit. The isolation means couple the sensor data output back to sensor data input. Isolation means include a single coupling device which couples energization, clock reference, sensor data and programming data across an electrically insulating barrier between the output circuit and the sensor circuit.

In a preferred embodiment, the single coupling device is a magnetic transformer.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a first embodiment of a transmitter according to the invention.

FIG. 2 shows a second embodiment of a transmitter according to the invention.

FIG. 3 shows a transformer circuit corresponding to FIG. 2.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1, a first embodiment of a transmitter according to the invention is shown in block diagram form. In FIG. 1, transmitter 50 is connected to loop 52. Loop 52 can be a two wire 4-20 mA industrial

control loop or a "multidrop" loop which supplies current to several transmitters in parallel. A 4 wire type circuit with 2 wires providing energization and two wires providing a 1-5 volt output can be used in place of loop 52, as well. Loop 52 supplies all of the energization to transmitter 50. Transmitter 50 is also coupled to a programming device 54 which can be a Rosemount Brand Model 268 providing programming via two way HART Brand digital communication protocol superimposed on the loop current.

Loop 52 supplies energization to power supply 56 which, in turn, energizes circuitry 60 on the left side of galvanic barrier 58 shown in dashed line form in FIG. 1. Current control 57 is coupled to the loop to control loop current and is coupled to microcomputer 66 to receive instructions. Current control 57 comprises a digital-to-analog current converter circuit. Clock oscillator 62 generates a timing reference or clock which is provided along line 64 to microcomputer 66 and driver circuit 68. Programming device 54 communicates with microcomputer 66 along line 70 to provide programming instructions which are stored in microcomputer 66. Driver circuit 68 generates an oscillatory driver output on line 72 which has a frequency controlled by clock oscillator 62. The output frequency is selected to be high enough so that it can be conveniently amplitude modulated with lower frequency modulations which carry programming data and sensed process parameter data. A drive frequency over 200 kilohertz is desirable to ensure fast enough updating of the transmitter output with process parameter information. A frequency range of 200 - 1000 kilohertz is acceptable for the drive frequency, with a range of

200 - 500 kilohertz being preferred. Driver output on line 72 is coupled to excite primary winding 74 of transformer 76. Microcomputer 66 couples a communication output on line 78 to control switch 80. Control switch 80 modulates the excitation current of transformer primary 74 with a communication signal representing programming instructions to be received by sensor circuit 82. The modulation is preferably amplitude modulation at a frequency lower than the excitation frequency.

Transformer 76 comprises primary winding 74 which is electrically insulated from secondary winding 75. Transformer 76 couples the modulated excitation to secondary 75. Secondary 75 is connected to diode 84 which rectifies the transformed isolated excitation and provides the excitation to filter 86. Filter 86 filters the excitation to extract the modulation provided by switch 80. The modulation is coupled along line 88 to waveshaping circuit 90 which provides further signal conditioning as needed. The output of waveshaper 90 provides the modulation which represents programming instructions to the sensor circuit 82. The sensor circuit 82 stores the programming instructions for programming the operation of the sensor circuit to adapt its characteristics to a particular measurement application. Characteristics such as span, zero, sampling rate, damping, calibration constants, and compensation for extraneous variables can be programmed in the sensor circuit 82 as desired. In the case of transmitters which are adapted in the field to a selected sensor, the programming can also adapt the sensor circuit to a selected sensor. For example, a temperature transmitter can be programmed to adapt it to

different types of thermocouples or resistance temperature detectors (RTD's).

Line 88 also couples excitation to a power supply filter 92 which provides a filtered power supply potential along line 94 to sensor circuit 82. Secondary winding 75 is coupled along line 96 to pulse shaper 98 which, in turn, provides shaped excitation to sensor circuit 82 as a clock or frequency reference. Sensor circuit 82 senses a process parameter 100 which can be temperature, pressure, flow, and the like. Sensor circuit 82 generates a serial digital output representing the process variable conditioned by the programming data stored in it along line 102 to control a switch 104 which modulates the power provided by the secondary to circuitry 106 on the right side of the barrier 58. Sense winding 108 of transformer 76 senses the modulation of the power and provides the modulation to microcomputer 66 via waveshaper 110 to provide microcomputer 66 with a signal representative of the sensed parameter adjusted for the programmed data stored in circuit 82. It is not essential that transformer 76 have three windings. Transformer 76 could also be configured with only two winding 74, 75, in which case waveshaper 110 would simply receive its input from winding 74.

The transformer 76 in FIG. 1 thus is a single isolation device which provides electrically insulated coupling of power, a clock frequency reference, a signal representative of the sensed parameter, and programming instructions, as well. The single transformer 76 of FIG. 1 thus provides galvanic isolation between loop circuitry such as output circuit 60 and sensor circuitry 106. The single transformer 76 not only couples

energization and a signal representative of the sensed parameter, but also couples a clock reference and programming signals across the barrier to maintain electrical isolation without providing additional transformers or other isolation devices in the transmitter.

In FIG. 2, a transmitter 150 is coupled to a two wire 4-20 milliampere loop 152 comprising a loop power supply 154 having a limited voltage and a readout device 156. As explained above in connection with FIG. 1, a programming device 158 is connected to the loop to provide programming to the transmitter. The programming device blocks lower frequency 4-20 mA loop current so that it does not interfere with loop operation.

The loop circuit is grounded to a ground system 160 at location 162. There are other electrical devices which are grounded to ground system 160 which inject noise currents i_N into the ground system at points 164. A sensor or sensors 166 are also coupled to ground system 160 at point 168. Because of the noise currents flowing in ground system 160, there is a noise potential difference E_N between points 162 and 168. If transmitter 150 included a completed electric circuit between the loop 152 and the sensors 166, noise ground currents would flow through transmitter 150 and loop 152, disturbing the measurement at readout 156. To avoid this problem, transmitter 150 is provided with a galvanic barrier 170 between circuitry connected to the loop 152 and the sensors 166. The galvanic barrier is an electrical open circuit which blocks electrical noise current flow, but still allows energy and information bearing signals to pass across the barrier using nonelectric transfer means such as the magnetic field of

a transformer. Each electrical component which has connections on opposite sides of barrier 170 must be an isolating component. Typically, isolation voltages on the order of 1,000 volts or more are desired. While this explanation of barriers, grounding and ground systems has been explained in connection with FIG. 2, it applies generally to FIG. 1, as well.

In transmitter 150, current control circuit 172 is connected to loop 152 at terminals 174. Current control circuit 172 is energized by current from loop 152 and provides energization along line 176 to other circuits on the left side of barrier 170. Current control 172 controls loop current as a function of a DAC output received on line 178 from DAC 180. Current control circuit 172 passes serial digital communication signals back and forth along line 182 between programming device 158 and MODEM 184. The digital communication signals include programming instructions and constants, for storage in circuitry on the right side of barrier 170. DAC 180 and MODEM 184 communicate along bus 186 with microcomputer 188. Microcomputer 188 provides a digital word representative of a parameter or parameters sensed by sensors 166 to both DAC 180 and MODEM 184. Microcomputer 188 stores programming constants provided by MODEM 184. Clock oscillator 190, which can be a crystal controlled oscillator, provides frequency or clock references to modem 184, microcomputer 188 and driver 192. Regulator 194 is energized by current control circuit 172 and provides a regulated supply potential along line 196 to driver 192.

Driver 192 drives an input of isolation device 198 along line 200 with an energy delivering waveform having a frequency controlled by clock oscillator 190.

The driver 192 modulates the waveform with data received on line 202 from microcomputer 188. The modulation represents programming constants for circuitry on the right side of barrier 170. Isolation device 198 electrically isolates lines 200, 204 from lines 206, 208, 209 while providing coupling across the barrier of energy and multiple signals using nonelectric coupling such as a magnetic field or light.

The isolation device 198 provides isolated energization on line 208 which is coupled to regulator rectifier 210. Regulator-rectifier 210 provides energization potentials to circuitry on the right side of barrier 170 and may also provide energization to one or more sensors 166. The isolation device 198 provides an output on line 206 which is a clock reference for analog to digital converter (ADC) 212. The output on line 206 is also coupled to filter 214 which extracts modulation data and provides it along line 216 to program characteristics of ADC 212. AbC 212 samples the output of one or more sensors 166 and couples a digital signal representative of the sensed parameters adjusted by the programming along line 218 to driver 220. Driver 220 modulates power drawn by isolation device 198 from driver 192 on the other side of the barrier. The modulation is preferably in the form of a serial digital signal. The isolation device 198 provides this modulation along line 204 to filter 222. Filter 222 coupled the data contained in the power modulation to microcomputer 188 where it is stored as an updated representation of the sensed parameter or parameters.

In FIG. 3, a circuit is shown which can be used in a transmitter such as the transmitter shown in FIG. 2 to couple power and multiple signals across a

galvanic barrier using a single isolating device, transformer 250. Transformer 250 includes a primary winding 252 electrically insulated from secondary winding 254 to form a galvanic barrier represented by dashed line 256. Drive transistor 258 is coupled in series with primary winding 252 and resistor 260 across a 10 volt power supply. Oscillating, and preferably sinusoidal current supplied by this arrangement excites the transformer so that it can deliver isolated power at its secondary winding 254. The level of drive is amplitude modulated by a field effect transistor 262 which has its output coupled in parallel with resistor 260 to vary current level in primary 252.

Secondary winding 254 energizes a regulator circuit comprising rectifier diode 264, filter capacitor 266, resistors 268, 274, zener diode 270, and capacitor 274. The regulator provides a supply potential or power to circuitry on the right side of barrier 256 which corresponds to barrier 170 of FIG. 2. Secondary 254 is coupled through resistor 276 and capacitor 278 to provide a clock reference at the drive frequency of driver 258. Filter 280 is coupled to secondary 254 through rectifier diode 264 and comprises resistors 282 and capacitors 286, 288. Filter 280 provides data at its output which represents the modulation provided by transistor 262. This modulation represents programming constants. A signal representative of sensed parameters is presented in serial digital form on line 290 to FET 292 which is connected in parallel across capacitor 294. Capacitor 294 is connected in series with secondary winding 254. The arrangement modulates the power drawn from driver 258 with the data representative of sensed parameters. This modulation appears on line 296 which

carries the data to a microcomputer such as microcomputer 188 of FIG. 2.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

WHAT IS CLAIMED IS:

1. A transmitter providing a transmitter output representing a sensed parameter to a loop which energizes the transmitter, comprising:

an output circuit receiving the energization from the loop and controlling the transmitter output as a function of a sensor data input, the output circuit further generating an oscillating driver output;

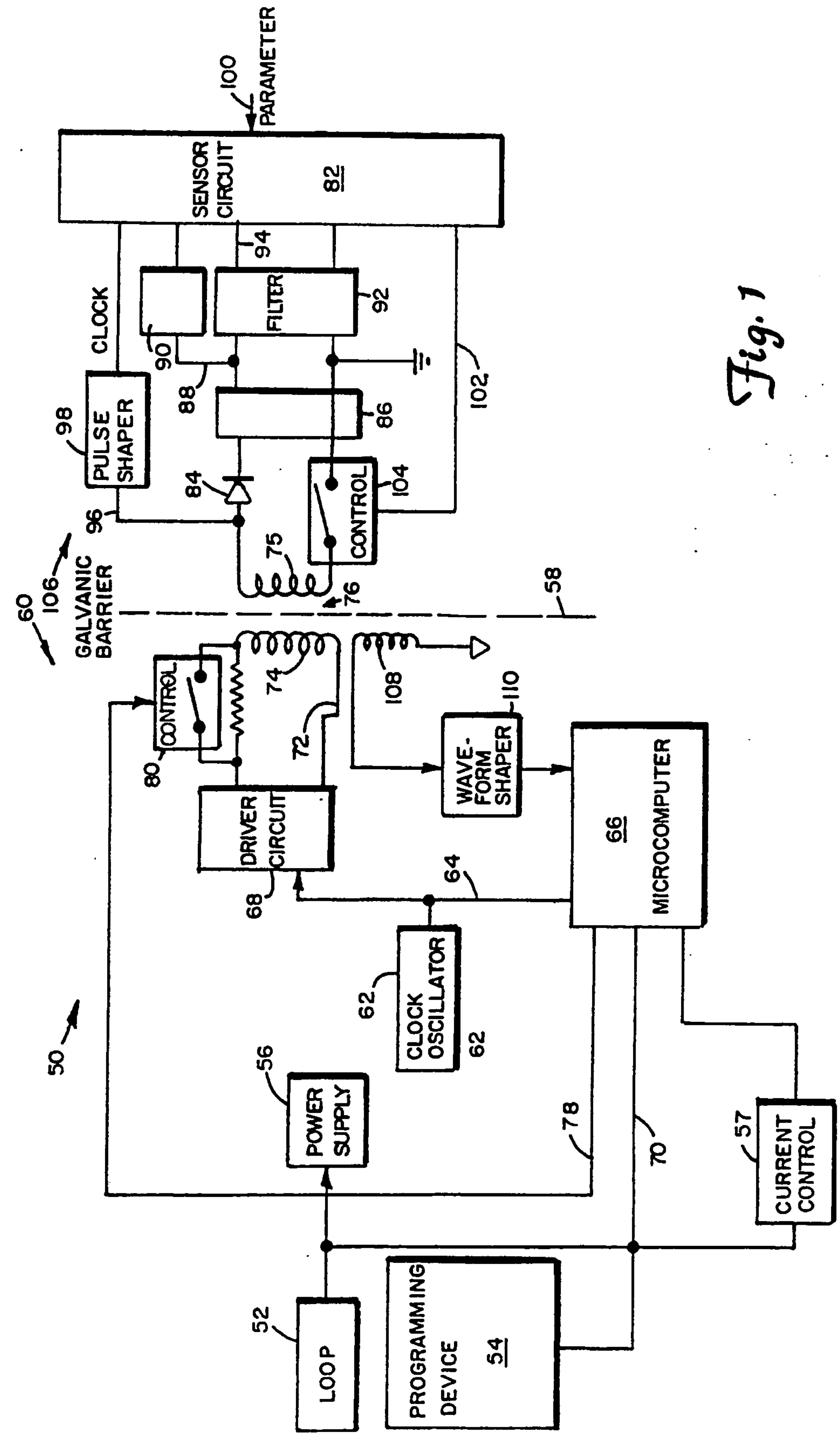
a sensor circuit generating a clocked sensor data output representing the sensed parameter; and

isolation means driven by the driver output for exciting the sensor circuit and for providing a clock reference as a function of the driver output oscillation to the sensor circuit, the isolation means providing the sensor data output back to sensor data input, the isolation means including a single coupling device which couples energization, sensor data and programming data across an electrically insulating barrier between the output circuit and the sensor circuit.

2. The transmitter of Claim 1 wherein the single coupling device further couples a clock reference between the output circuit and the sensor circuit.

3. The transmitter of Claim 1 wherein the single coupling device is a magnetic transformer having a first

winding coupled to the output circuit and a second winding electrically insulated from the first winding and coupled to the sensor circuit.


PARAMETER
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SENSOR CIRCUIT
82
CLOCK
94
FILTER
92
90
88
86
102
PULSE SHAPER
98
84
CONTROL
104
96
75
60
106
GALVANIC BARRIER
76
58
CONTROL
74
108
110
72
80
DRIVER CIRCUIT
WAVE-FORM SHAPER
MICROCOMPUTER
66
64
68
CLOCK OSCILLATOR
62
62
50
56
POWER SUPPLY
78
70
57
CURRENT CONTROL
52
LOOP
PROGRAMMING DEVICE
54

Fig. 1

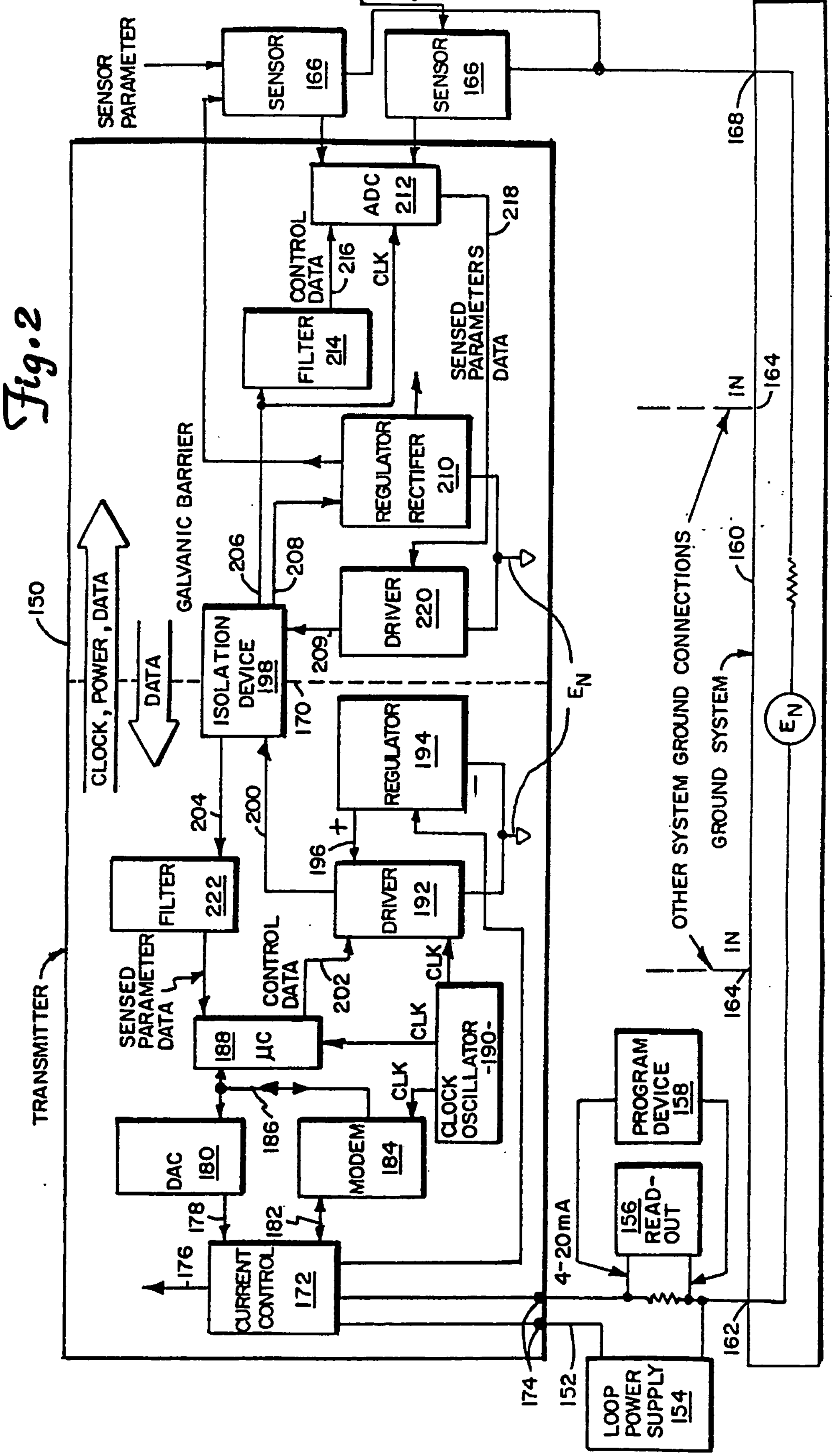
Fig. 2
SENSOR PARAMETER
SENSOR 166
SENSOR 166
ADC 212
CONTROL DATA
216
CLK
218
FILTER 214
SENSED PARAMETERS DATA
168
REGULATOR RECTIFER 210
GALVANIC BARRIER
CLOCK, POWER, DATA
DATA
150
206
208
ISOLATION DEVICE 198
DRIVER 220
209
170
REGULATOR 194
E N
IN
164
OTHER SYSTEM GROUND CONNECTIONS
160
GROUND SYSTEM
E N
204
200
196
FILTER 222
DRIVER 192
SENSED PARAMETER DATA
CONTROL DATA
202
CLK
188 μC
CLK
CLOCK OSCILLATOR -190-
CLK
TRANSMITTER
DAC 180
186
MODEM 184
IN
164
PROGRAM DEVICE 158
156 READ-OUT
4-20mA
178
182
176
CURRENT CONTROL 172
174
152
LOOP POWER SUPPLY 154
162

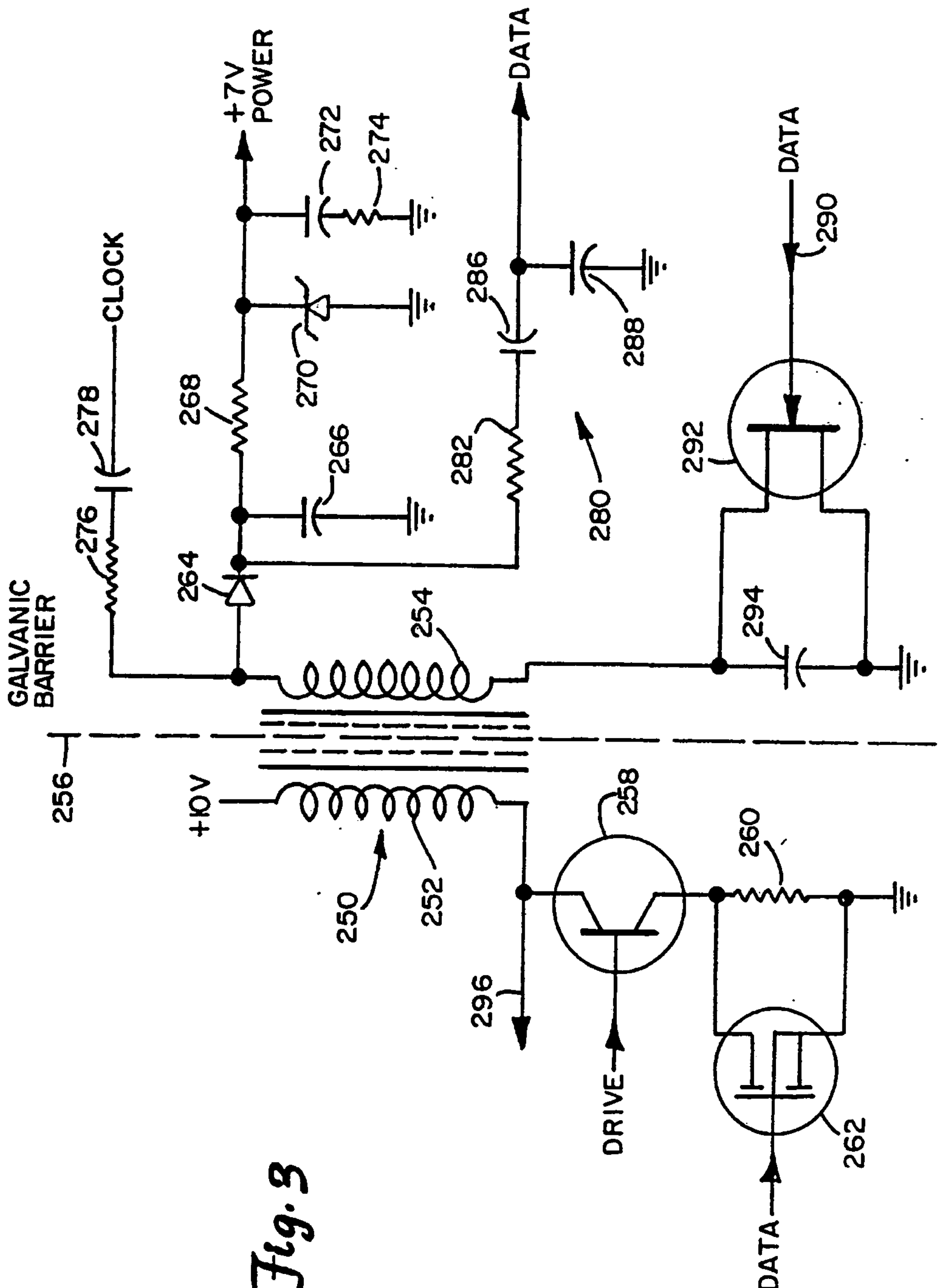
+7V
POWER
DATA
CLOCK
DATA
GALVANIC
BARRIER
+10V
DRIVE
DATA
250
252
254
256
258
260
262
264
266
268
270
272
274
276
278
280
282
286
288
290
292
294
296

Fig. 3

INTERNATIONAL SEARCH REPORT

International Application No PCT/US91/01210

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5): G08C 19/06
US CL : 340/870.31,870.39,870.16

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
US	340/870.16,870.18,870.19,870.31,870.39,825.54 340/310P; 455/41

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No [18]
Y	US, A, 4,354,190 (Reschovsky) 12 October 1982, See abstract last 4 lines, column 3 line 54-column 4 line 28.	1-3
Y	US, A, 4,758,836 (Scuilli) 19 July 1988 See column 5, line 13-22, column 7 lines 50-53.	1-3

* Special categories of cited documents: [15]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
29 APRIL 1991	20 MAY 1991
International Searching Authority [1]	**Signature of Authorized Officer** [20]
ISA/US	Michael Horabik

Form PCT/ISA/210 (second sheet) (May 1986)